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REFURBISHMENT OF NASA AIRCRAFT WITH FIRE-RETARDANT MATERIALS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

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16. Abstract

A NASA executive aircraft cabin refurbishment program to evaluate selected fire-retardant materials for possible application to commercial aircraft is described. The results of flammability screening tests and information on the physical and chemical properties of both original and newly installed materials after extended use are presented in tabular form, with emphasis on wear properties, strength, puncture and tear resistances, and cleanability.

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REFURBISHMENT OF NASA AIRCRAFT WITH FIRE-RETARDANT MATERIALS

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REFURBISHMENT OF NASA AIRCRAFT

WITH FIRE-RETARDANT MATERIALS

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SUMMARY

The interiors of four NASA Gulfstream executive aircraft were refurbished with materials proven by laboratory and full-scale aircraft flammability tests to have flammability and offgassing characteristics superior to those used in aircraft prior to 1968. The purpose in refurbishing the aircraft was to evaluate the selected materials in aircraft operations so that physical characteristics such as wear, durability, and cleanability could be further examined. Most materials used for refurbishment were newly developed materials that had been found promising in laboratory tests and some materials developed by space research and used successfully in the Apollo and Skylab Programs.

INTRODUCTION

Many commercial aircraft accidents involve fires on the ground or in flight. To minimize the fire threat inside the aircraft and to extend the evacuation time for the passengers, interior cabin furnishings must be made as fire resistant as possible. During the Apollo and Skylab Programs, new fire-resistant materials were developed for use in the spacecraft, and data on these materials were presented at a symposium held at the NASA Lyndon B. Johnson Space Center (JSC) in 1970 (ref. 1).

To demonstrate the adaptability of these and other newly developed materials to commercial aircraft, JSC initiated a test program designed to evaluate both flammability and physical properties under aircraft use conditions. The flammability tests were performed in an aircraft fuselage section, and the description and test results are contained in reference 2. Four NASA Gulfstream executive aircraft, scheduled for routine maintenance and refurbishment, were utilized as test vehicles for demonstrating the physical properties of the selected fire-resistant materials under actual flight use conditions. Although both test programs — the full-scale flammability and the refurbishment tests — are closely related, this report is concerned only with the status of the Gulfstream Aircraft Cabin Materials Development Program.

The full-scale flammability tests were conducted to compare the flammability properties of materials used in aircraft prior to 1968 with the new fire-retardant materials selected as potential replacements for the old materials. Results of the tests (ref. 2) indicated that the pre-1968 materials ignited easily, allowed the fire to spread, produced large amounts of smoke and toxic combustion products, and were capable of supporting a flash fire with major damage. The newer fire-resistant materials were found to restrict fire propagation, to decompose rather than ignite, and generally to resist combustion. As a result, less smoke was produced and lower concentrations of toxic combustion products and lower cabin temperatures were noted.

The basic objective of the Gulfstream refurbishment program was to provide information on the durability, wearability, and cleanability of highly flame-resistant materials. Only materials that could be readily fabricated at reasonable cost were selected so that such materials might be considered for application in commercial aircraft. This objective was to be met within the constraints of the refurbishment schedules for the NASA executive aircraft.

The author wishes to acknowledge the assistance of the following persons who contributed to the progress of the program: Arthur Ringwood and Elizabeth Gauldin of General Electric Company; Michael Baust and H. V. Zaremba of AiResearch Aviation Company; R. L. Shanklin and Lee Hundley of Mosites Rubber Company, Incorporated; J. V. Owens and R. L. Holmes of Raybestos-Manhattan Corporation; Joseph Keating and D. A. Stivers of 3M Company; and John Szabat and W. C. Darr of Mobay Chemical Company.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Système International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

LABORATORY SCREENING TESTS

The materials selected for the Gulfstream refurbishment program were subjected to flammability testing and chemical property evaluation in the laboratory. Table I contains the specific test criteria required for the materials, including features required of aircraft cabin interior materials for which no specific laboratory evaluation tests are available. Table II identifies materials used in the program and their manufacturing source.

The limiting oxygen index (LOI) measures the minimal volume fraction of oxygen in a slowly moving oxygen/nitrogen atmosphere that will support flaming combustion. The material is placed or suspended vertically in a chamber and ignited at the top. The test provides a reproducible measure of the intrinsic flammability of a material. Previously, materials were tested by the Federal Aviation Agency (FAA) vertical test method, in which the sample is hung vertically in the chamber and ignited at the bottom in ambient air; after 12 seconds, the ignition source is removed. The afterflame, afterglow, and char length are measured and recorded. In this program, the FAA procedure was used only as a screening test to indicate whether further flammability tests should be performed.

Smoke generation is measured by optical methods. The material is subjected to a heat source in a chamber and the loss of light transmittance through the chamber is utilized to calculate the amount of smoke evolved. Smoke generation is measured in terms of the specific optical density, or DSM. The time for the optical density to reach a value associated with a person's ability to find his way out of a smoke-filled room is also of interest and may be used as a test criterion.

The thermogravimetric (TGA) test provides a thermal degradation profile of a material. A small sample of material is heated at a temperature rise rate of 15 K (15° C) per minute in a chamber with a given atmosphere which, in this case, is air. The weight loss of the material as a function of the increasing temperature is recorded on a chart, and the temperature at which degradation begins is noted by a fairly sudden downward dip in the recorder penline. The temperature at which this dip commences is taken as the point at which the high rate of potentially toxic off-gassing occurs. The test supplements but does not replace complete offgassing analysis and toxicity tests. The TGA criterion of 478 K (400° F) is based on studies that indicate that human beings cannot survive more than several seconds when exposed to a temperature of 478 K (400° F). Thus, if a material is thermally stable to 478 K (400° F), the passengers will have more time to evacuate the aircraft in case of a fire with less risk of being overcome by toxic gases.

Physical properties such as strength, flexibility, and abrasion resistance are determined mechanically in the laboratory by using an Instron machine for testing tensile, elongation, and flexural strength and a Taber abrader for testing abrasion resistance and wearability. Because the materials selected for the refurbishment program were to be evaluated for functional and physical properties by their performance in real-time flight use, only the qualitative screening tests previously noted were performed in the laboratory. Thus, no information on physical properties alone appears in this report. The results of the flammability, smoke, and TGA tests are given in table III(a) for newly developed polymeric coating and foam materials and in table III(b) for commercially available textile materials. These textile materials were used because they were available, were found adequate, and did not require screening through a costly and time-consuming fiber and development program.

GULFSTREAM REFURBISHMENT PROGRAM

Of the four executive aircraft, NASA JSC Gulfstream 2 was the first to be refurbished. Since this initial refurbishment was accomplished on a restrictive schedule, the effort was only partially successful. Two problems were encountered: the lack of fabrication quality of some materials and the nonapplicability of the space materials to commercial aircraft.

To initiate the refurbishment program while the aircraft was scheduled for routine maintenance, some materials had to be fabricated at JSC. The quality of the fabrication did not reflect professional standards, particularly since materials processing and coating techniques were still in the developmental stages. However, the installations of the side panels, curtains, ceiling panels, lavatory, and steward room walls were satisfactory. Spinoff materials from the Apollo Program were used

in the aircraft and many of these materials were not applicable to commercial aircraft because of their high cost and their resistance to dyes. For example, polybenzimidazole (PBI) and Durette are expensive and can only be obtained in their natural colors, which are brown and gold. Some materials also lacked certain physical properties such as durability (when used over extended periods) and acceptable cleaning characteristics.

The second problem was related to the failure in adapting certain other spinoff materials to commercial aircraft, thereby leading to the use of materials that were not as serviceable as the materials they replaced. For example, the fabric coatings applied at JSC showed delamination of the coating from the substrate after a period of use because inadequate processing techniques were used (fig. 1). Flovan-treated wool, for example, replaced the Fluorel-coated artificial-leather-type material for the crew seat upholstery trim and for the armrests throughout the aircraft. However, when soiled, the wool proved to be difficult to clean and had to be replaced with fire-retardant leather.

The refurbishment of the NASA Headquarters aircraft, Gulfstream 1, was carried out immediately prior to the Apollo 16 launch. Because it was desirable to have the aircraft fitted with firesafe materials in time for the Apollo 16 launch, the schedule for completing the task was restrictive. The installations were almost identical to those of Gulfstream 2. Some coated fabrics were installed in Gulfstream 1 shortly before it was discovered that they were failing in Gulfstream 2. Material failures were similar to those in Gulfstream 2; in addition, the fiberglass carpet proved unsatisfactory (fig. 2), and the curtain that closed off the galley from the cockpit showed water stains. These fabrics were replaced as more durable materials were developed and became available. All replacement materials have been observed to be in satisfactory condition since their installation.

The results encountered during the initial refurbishment phases do not indicate a lack of success in providing fire-retardant materials. Table IV, which shows the Gulfstream 1 and 2 refurbishment status, indicates that notable successes were achieved among those materials originally installed (fig. 3). Thus, these materials were made commercially available from a number of different suppliers at market prices. Detailed identification of the various fabrics utilized in the refurbishment program is contained in table III.

Refurbishments of the NASA George C. Marshall Space Flight Center Gulfstream 3 and the NASA John F. Kennedy Space Center Gulfstream 4 were scheduled but delayed until the anomalies observed in the Gulfstream 1 and 2 aircraft were resolved and corrected. By this time, new materials had been evaluated for physical, chemical, and flammability properties and found acceptable. The selected materials were then procured and installed in the aircraft. The performance results of the materials installed in the Gulfstream 1 and 2 aircraft are shown in table IV; those for the Gulfstream 3 and 4 aircraft are contained in table V.

Some of the new materials developed to meet specific applications during the refurbishment program have included Kel-F-coated asbestos for the entrance, Kel-F-coated nylon for the lavatory, and a lower cost scrim-supported Nomex felt sandwiched between two layers of Fluorel-coated Nomex overcoated with Kel-F FX 703 for the acoustical drape (figs. 4 to 7).

FUTURE EFFORTS

The refurbishment program was undertaken with the intent of extending the technology to commercial aircraft applications; therefore, new materials such as improved coated fabrics and molded parts are being procured from vendors for continued evaluation and testing. Vendors are being selected to perform development work on fire-retardant foams. Because commercial aircraft are structurally and functionally quite similar to the Gulfstream-type aircraft, materials that have been installed in the NASA aircraft and those that have been evaluated without specific application to the Gulfstreams are being considered for commercial application. A fire-retardant artificial-leather-type trim material is urgently needed, as are lightweight rigid materials for fire-retardant structural and flooring applications. Some of the latter types will be tested in the near future.

CONCLUDING REMARKS

The NASA Gulfstream executive aircraft have been used as test beds for observing and determining the durability and maintainability (cleanability) of the fire-retardant materials with which they were refurbished. The materials had been screen tested in the laboratory and (full scale) in the 737 fuselage for flammability and thermal stability; they met the requirements satisfactorily. Concerning the physical requirements, it was deemed unfeasible to screen test laboratory samples because the results could not be adequately related to actual full-scale usage. Therefore, the executive aircraft were fitted full scale with the selected materials and the wearability and cleanability noted. As indicated in tables IV and V, some of the materials did not stand up under the flight usage and environment and were replaced with newly developed and more adaptable materials. All items are performing satisfactorily after nearly 2 years in service, which actually exceeds expectations. Fortunately, a sufficient number of the newly developed materials were available for refurbishing the four Gulfstream aircraft, but at a premium cost because of the small job lots requested. An increasing number of manufacturers, recognizing the potential use of fire-retardant materials in commercial aircraft, as well as in other consumer applications, have shown an interest in undertaking their own development programs. This should result in adequate supply and wider selection of materials at lower costs. Some of these materials are already proving acceptable and durable under actual flight conditions.

A continuation of the materials development work to accomplish the overall objectives of the NASA Gulfstream aircraft refurbishment program is recommended.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, October 16, 1975
501-38-19-31-72

REFERENCES

1. Conference on Materials for Improved Fire Safety. NASA SP-5096, 1971.

2. Stuckey, Robert N.; Supkis, Daniel E.; and Price, James L.: Full-Scale Aircraft Cabin Flammability Tests of Improved Fire-Resistant Materials. NASA TM X-58141, 1974.

TABLE 1.- AIRCRAFT CABIN MATERIALS TEST CRITERIA

Characteristic	Criteria
Flammability	Limiting oxygen index (LOI), minimum of 30
Smoke generation	Maximum specific optical density (DSM), range of 50 to 75
Thermogravimetric analysis (TGA)	Thermally stable to 478 K (400° F)
Durability	Material must maintain appearance, wearability, tensile strength, flexibility, and abrasion resistance during periods between routine maintenance and refurbishment
Weight	Minimum required to ensure physical properties; total weight of new installations shall not exceed that of those currently used
Esthetics	Material must be attractive in appearance, bright, and lifelike; must have good drape; and must be properly fitted
Ease of fabrication and installation	Materials must be easily and inexpensively patterned and fabricated into configurations readily installed in aircraft; no major retooling shall be required
Clearability	Materials must be easily cleaned with ordinary detergents and water without use of harsh cleaners or solvents
Colorfastness	Materials must retain color quality and brightness during useful life
Availability and cost	Materials must be commercially available or have potential for commercial output at reasonable cost competitive with similar materials

TABLE II.- MATERIALS IDENTIFICATION AND SOURCE

Material	Source
Scott high resiliency (HR) foam and Pyrell foam padding	Scott Paper Co. Foam Div. 1500 E. Second St. Chester, Pa. 19013
Ammonium dihydrogen phosphate (ADP)	Fisher Scientific Co. 4102 Greenbriar Dr. Houston, Tex. 77006
Fluorel L-3203-6, tan L-3961-5, white	Raybestos-Manhattan Industrial Products Co. North Charleston Div. Garco Street and O'Hear Ave. North Charleston, S.C. 29406
Meteor cobalt blue Pigment #7540 for Fluorel, blue and oyster-white	The Harshaw Chemical Co. Division of Kewanee Oil Co. 3415 Bardstown Rd. Louisville, Ky. 40216
Ensolite foam, type M, off-white	Uniroyal Expanded Products Department Mishawaka, Ind. 46544
Flovan-treated wool, gray, Langenthal S/2040, C74	Intercel Corp. P.O. Box 2005 Bellevue, Wash. 98009
50-percent wool/50-percent Leavil upholstery fabric, Langenthal S-M08965, C-45	Intercel Corp. P.O. Box 2005 Bellevue, Wash. 98009
Flovan-treated wool, blue, Langenthal S-Poker 1100, 42 blue	Intercel Corp. P.O. Box 2005 Bellevue, Wash. 98009
Fire-retardant leather, ginger color, nudo	Eagle Ottawa Leather Co. Division of Albert Trostel & Sons Co. Grand Haven, Mich. 49417
Kel-F FX 703	3M Co. St. Paul, Minn. 55101
Modacrylic ticking cloth, Weftamatic, 58-percent SEF, S-6186, yellow	J. P. Stevens & Co., Inc. 1185 Avenue of the Americas New York, N.Y. 10036

TABLE II.- MATERIALS IDENTIFICATION AND SOURCE - Concluded

Material	Source
Disposable fire-retardant nonwoven cellulose, S/AK 770	Chicopee Mills Milltown, N.J. 08850
100-percent wool pile carpet, blue-black, Bigelow Gropoint S-2097	Bigelow-Sanford, Inc. Thompsonville, Conn. 06082
Kel-F 2401B coated asbestos, linoleum type	3M Co. Film and Allied Products Div. P.O. Box 559 Monrovia, Calif. 91017
Beta Fiberglas, white, S-4065, F-026 finish	Owens/Corning Fiberglas Ashton, R.I. 02864
Nomex scrim-supported Nomex felt, S-1872 NR	Globe-Albany Corp. Auburn, Maine 04210
Blue Fluorel L-3203-6 coated Nomex fabric, S-RL 4988-1	Raybestos-Manhattan Industrial Products Co. North Charleston Div. Garco St. and O'Hear Ave. North Charleston, S.C. 29406
White Fluorel L-3961-5 coated fiberglass S-RL4417	Raybestos-Manhattan Industrial Products Co. North Charleston Div. Garco St. and O'Hear Ave. North Charleston, S.C. 29406
White Fluorel L-3961-5 coated Durette 400-5	NASA Lyndon B. Johnson Space Center Houston, Tex. 77058
Mobay HR foam no. 115014-6	Mobay Chemical Co. Division of Baychem Corp. Pittsburgh, Pa. 15205
Fire-retardant lambswool, material shearling lambskin, 1.27 cm (0.5 in.) softlamb BB	AC Lawrence Leather Co. Sawyer St. Peabody, Mass. 01960
Wool, solid-blue, synproof-treated, S-1900, 17 blue	Rancocas Fabrics 979 Third Ave. New York, N.Y. 10022
Blue Kel-F 2401E coated nylon	Mosites Rubber Co., Inc. P.O. Box 2115 Fort Worth, Tex. 76105
Fire-retardant leather, blue, Vista A/1271B	Garden State Tanning, Inc. Fleetwood, Pa. 19522

TABLE III SMOKE, FLAMMABILITY, AND TGA TEST RESULTS

(a) Newly developed polymeric coatings and foam materials

Application	Material		LDH		Smoke, DSM		Afterflame, sec		FAA flammability afterglow, sec		Char length, cm (in.)		TGA[a]	
	Identification													
	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement
Headliner, side panels, cockpit ceiling, window panels, and cabin air-duct shrouds	Vinyl coated fabric	White Fluorel L 3961 5 coated fiberglass overcoated with Kel-F FX 703	28	99	132	10	0	0	0	3 6	15 2 (6)	0 3 (0.13)	4	1
Seat back, cushion, and carpet pad	Polyurethane foam	Scott and Molsey HR foam treated with ADP and coated with Fluorel L 3203 6	17	58	162	105	0	0	0	0	12 7 (5)	1 3 (5)	9	6
Entrance wall and acoustical curtain	Embossed vinyl coated fabric	Blue Fluorel L 3203 6 coated Nomex fabric overcoated with Kel F FX 703	21	56	282	23	Sample burned	0		0		2.5 (1)	3	2
Lavatory, steward room, and coat closet walls	Heavy vinyl coated fabric	White Fluorel L 3961 5 coated Durette 400 5 overcoated with Kel F FX 703	25	40	132	9	0	0	0	2	15 2 (6)	6 4 (2 5)	4	4
Galley and lavatory floors	Heavy vinyl coated fabric	Kel F 2401B coated asbestos, linoleum type	25	99	175	15	18	0	0	0	15 2 (6)	6 (3)	4	1
Toilet shroud	Vinyl coated fabric	Kel F 2401E coated nylon	25	43	132	36	0	0	0	0	15.2 (6)	8.9 (3 5)	4	1
Wall padding	Polyurethane foam	Pyrell foam	17	24	362	96	0	0	0	0	12.7 (5)	8.9 (3 5)	9	4

[a]Percent weight loss at 478 K (400° F)

TABLE III.- SMOKE, FLAMMABILITY, AND TGA TEST RESULTS

(a) Newly developed polymeric coatings and foam materials

Application	Material		LOI		Smoke, DSM		Afterflame, sec		FAA flammability afterglow, sec		Char length, cm (in.)		TGA[a]	
	Identification													
	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement
Headliner, side panels, cockpit ceiling, window panels, and cabin air-duct shrouds	Vinyl coated fabric	White Fluorel L 3961 5 coated fiberglass overcoated with Kel-F FX 703	28	>99	132	10	0	0	0	3.6	15.2 (6)	0.3 (0.13)	4	1
Seat back, cushion, and carpet pad	Polyurethane foam	Scott and Mobay HR foam treated with ADP and coated with Fluorel L 3203 6	17	58	362	105	0	0	0	0	12.7 (5)	1.3 (.5)	9	6
Entrance wall and acoustical curtain	Embossed vinyl coated fabric	Blue Fluorel L 3203 6 coated Nomex fabric overcoated with Kel F FX 703	21	56	282	23	Sample burned	0		0		2.5 (1)	3	2
Lavatory, steward room, and coat closet walls	Heavy vinyl-coated fabric	White Fluorel L 3961 5 coated Durette 400 5 overcoated with Kel F FX 703	25	40	132	9	0	0	0	2	15.2 (6)	6.4 (2.5)	4	4
Galley and lavatory floors	Heavy vinyl coated fabric	Kel F 2401B coated asbestos, linoleum type	25	>99	175	35	18	0	0	0	15.2 (6)	.6 (.3)	4	1
Toilet shroud	Vinyl coated fabric	Kel F 2401E coated nylon	25	43	132	36	0	0	0	0	15.2 (6)	8.9 (3.5)	4	1
Wall padding	Polyurethane foam	Pyrell foam	17	24	362	96	0	0	0	0	12.7 (5)	8.9 (3.5)	9	4

[a]Percent weight loss at 478 K (400° F)

TABLE III. - SMOKE, FLAMMABILITY, AND TGA TEST RESULTS - Concluded

(b) Textile materials

Material			LOI		Smoke, DSM		Afterflame, sec		FAA flammability afterglow, sec		Char length, cm (in.)		TGA[a]	
Application	Identification													
	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement
Passenger upholstery NASA nos. 1,2,3	Fire-retardant blend: rayon (50 percent), wool (25 percent), nylon (25 percent)	50/50 wool/Leavil blend	38	36	127	148	0	0	0	0	6.4 (2.5)	7.6 (3)	19	10
Upholstery NASA no. 4	Fire-retardant blend: rayon (50 percent), wool (25 percent), nylon (25 percent)	Wool (100 percent) blue	30	34	127	79	0	0	0	0	6.4 (2.5)	0.4 (1.0)	19	11
Pilot seat upholstery	Untreated wool	Fire-retardant lambswool	26	30	45	164	Sample burned	0	.	0	.	1.9 (.8)	15.5	13
Pilot seat trim and armrests, passenger seat trim and armrests and footrests	Fire-retardant top-grain cowhide leather, massaged	Fire-retardant leather, blue, Vista A/1271B	32	30	201	348	0	15	20	5	5.1 (2)	1.9 (.8)	15	15
Pilot seat trim (NASA nos. 1 and 2)	Fire-retardant top-grain cowhide leather, massaged	Fire-retardant leather, ginger color	32	35	201	146	0	9	20	36	5.1 (2)	3.2 (1.3)	15	10
Ticking	No ticking	Modacrylic	-	25	.	92	.	0	.	0	.	11.4 (4.5)	-	10
Curtain	Fire-retardant-treated rayon/cotton, skyline turquoise color	Flovan-treated wool, blue	42	33	20	33	0	0	2	0	5.1 (2)	5 (2)	25	15
Curtain lining	Fire-retardant-treated cotton	Beta Fiberglas fabric	32	>99	51	2	0	0	0	0	10.2 (4)	.6 (.3)	10.5	<1
Floor covering	Wool (100 percent) pile carpet	Wool (100 percent) pile carpet, blue-black	31	31	109	109	0	0	35	35	1.3 (.5)	1.3 (.5)	9	9
Headrest cover	Vinyl-coated fabric	Disposable fire-retardant nonwoven cellulose	25	32	132	15	0	0	0	0	15.2 (6)	14.6 (5.8)	4	27
Acoustical curtain	Ensolite	Nomex scrim-supported Nomex batting	29	34	518	109	0	0	5	13	7.6 (3)	3.8 (1.5)	33	7

[a]Percent weight loss at 478 K (400° F).

TABLE III. - SMOKE, FLAMMABILITY, AND TGA TEST RESULTS - Concluded

(b) Textile materials

Material			LOI		Smoke, DSM		Afterflame, sec		FAA flammability afterglow, sec		Char length, cm (in.)		TGA[a]	
Application	Identification													
	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement	Original	Replacement
Passenger upholstery NASA nos. 1,2,3	Fire-retardant blend: rayon (50 percent), wool (25 percent), nylon (25 percent)	50/50 wool/Leavil blend	30	36	127	148	0	0	0	0	6.4 (2.5)	7.6 (3)	19	10
Upholstery NASA no. 4	Fire-retardant blend: rayon (50 percent), wool (25 percent), nylon (25 percent)	Wool (100 percent) blue	30	34	127	79	0	0	0	0	6.4 (2.5)	4.4 (1.8)	19	11
Pilot seat upholstery	Untreated wool	Fire-retardant lambswool	26	30	45	164	Sample burned	0	-	0	-	1.9 (.8)	15.5	13
Pilot seat trim and armrests, passenger seat trim and armrests and footrests	Fire-retardant top-grain cowhide leather, massaged	Fire-retardant leather, blue, Vista A/1271B	32	30	201	348	0	15	20	5	5.1 (2)	1.9 (.8)	15	15
Pilot seat trim (NASA nos. 1 and 2)	Fire-retardant top-grain cowhide leather, massaged	Fire-retardant leather, ginger color	32	35	201	346	0	9	20	36	5.1 (2)	3.2 (1.3)	15	10
Ticking	No ticking	Modacrylic	-	25	-	92	-	0	-	0	-	11.4 (4.5)	-	10
Curtain	Fire-retardant-treated rayon/cotton, skyline turquoise color	Flovan-treated wool, blue	42	33	20	33	0	0	2	0	5.1 (2)	5 (2)	25	15
Curtain lining	Fire-retardant-treated cotton	Beta Fiberglas fabric	32	>99	51	2	0	0	0	0	10.2 (4)	.6 (.3)	10.5	<1
Floor covering	Wool (100 percent) pile carpet	Wool (100 percent) pile carpet, blue-black	31	31	109	109	0	0	35	35	1.3 (.5)	1.3 (.5)	9	9
Headrest cover	Vinyl-coated fabric	Disposable fire-retardant nonwoven cellulose	25	32	132	15	0	0	0	0	15.2 (6)	14.6 (5.8)	4	27
Acoustical curtain	Ensolite	Nomex scrim-supported Nomex batting	29	34	518	109	0	0	5	13	7.6 (3)	3.8 (1.5)	33	7

[a]Percent weight loss at 478 K (400° F).

TABLE IV.- GULFSTREAM 1 AND 2 REFURBISHMENT EVALUATION

Material application	Material initially installed	Performance	Material currently installed	Performance
Seat back cushions	NASA no. 1 - Scott HR foam impregnated with ADP and overcoated with Fluorel L-3203-6; Scott HR foam installed in NASA no. 2 not treated because of tight schedule	Satisfactory	No change required	--
Seat flotation cushions	Composite of Ensolite foam and Scott HR foam; NASA no. 1 - Scott HR foam impregnated with ADP and overcoated with Fluorel L-3203-6	Satisfactory	No change required	--
Crew seat upholstery	Flovan-treated wool (100 percent), gray	Acceptable; however, too warm and has tendency to pilling in severe wear areas	Fire-retardant lambswool	Satisfactory
Crew seat trim and armrests	Trim composed of Nomex scrim-coated with blue marbleized Fluorel and overcoated with Kel-F FX 703 for easy cleaning	Unsatisfactory; Fluorel coating delaminated from scrim during sewing operations	Fire-retardant leather, ginger color	Satisfactory
Passenger seat upholstery	Fire-retardant Flovan-treated blue wool, blends for seat and back seat cover	Acceptable; however, fabric tended to pucker, sag, and show pilling after period of use	Wool/Leavil blend fabric upholstery and modacrylic ticking (fig. 4)	Satisfactory
Passenger seat armrests and footrests	Fire-resistant Nomex, scrim-coated with blue marbleized Fluorel L-3203-6 and overcoated with Kel-F FX 703	Unsatisfactory; Fluorel coating delaminated from scrim during sewing operations	Fire-retardant leather, blue	Satisfactory
Headrest covers	Disposable fire-retardant nonwoven cellulose	Satisfactory	No change required	--
Entrance, galley and lavatory floors, and lower sidewalls	Fire-retardant acrylic-coated fiberglass carpeting	Unsatisfactory; stains impossible to clean	NASA no. 1 - Wool (100 percent), blue-black pile installed as an interim material	Wool not recommended because pile retains debris and spilled liquids; Kel-F 2401B coated asbestos linoleum-type can be supplied as an alternate upon request
			NASA no. 2 - Kel-F 2401B coated asbestos linoleum-type installed	Satisfactory
Carpeting, passenger cabin	NASA no. 1 - Fire-retardant acrylic-coated fiberglass	Unsatisfactory; stains impossible to clean	Wool (100 percent), blue-black pile	Satisfactory
	NASA no. 2 - Wool (100 percent), blue-green	Acceptable; however, replacement required after 2 years of unusually severe service	Wool (100 percent), blue-black pile	Satisfactory
Side curtains	Flovan-treated wool, blue, lined with Beta Fiberglas, white	Satisfactory	NASA no. 1 - Fire-retardant cotton with fire-retardant cotton lining installed per cognizant personnel preference	Satisfactory
			NASA no. 2 - No change required	--
Coat closet drape	Fiberglass, blue print, with Durette liner	Unsatisfactory; very difficult to clean when soiled	NASA no. 1 - Flovan-treated wool, blue, with modacrylic lining	Satisfactory
			NASA no. 2 - Flovan-treated wool, blue, reversible curtain	Satisfactory
Acoustical entrance drape	Durette batting sandwiched between two layers of blue Fluorel L-3203-6 coated Durette overcoated with Kel-F FX 703	Unsatisfactory; Fluorel delaminated from the Durette	Nomex scrim-supported Nomex felt sandwiched between two layers of blue Fluorel L-3203-6 coated Nomex fabric, overcoated with Kel-F FX 703	Satisfactory

TABLE IV.- GULFSTREAM 1 AND 2 REFURBISHMENT EVALUATION - Concluded

Material application	Material initially installed	Performance	Material currently installed	Performance
Cockpit drape	Flovan-treated wool, blue	Satisfactory; however, soiled beyond cleaning and replacement required	Flovan-treated wool, blue	Satisfactory
Headliner and side panels	White Fluorel L-3961-5 coated fiberglass, overcoated with Kel-F FX 703	Satisfactory	No change required	--
Cabin air-duct shrouds	White Fluorel L-3961-5 coated fiberglass, overcoated with Kel-F FX 703	Satisfactory	No change required	--
Toilet shrouds	Blue Fluorel L-3203-6 coated Durette, overcoated with Kel-F FX 703	Satisfactory	No change required	--
Window panels	Fiberglass coated with white Fluorel L-3961-5, overcoated with Kel-F FX 703	Satisfactory	No change required	--
Entrance wall	Blue Fluorel L-3203-6 coated Durette, overcoated with Kel-F FX 703	Unsatisfactory; edges wore severely	Blue Fluorel L-3203-6 coated Nomex fabric, overcoated with Kel-F FX 703 (fig. 5)	Satisfactory
Lavatory, steward room and coat closet walls	Durette coated with white Fluorel L-3961-5, overcoated with Kel-F FX 703 with 0.3175 cm (0.125 in.) Pyrell pad coated with Fluorel L-3203-6	Satisfactory	No change required	--
Window frames	Existing frames coated with white Fluorel, and overcoated with Kel-F FX 703	Unsatisfactory; material showed scratches and chips	Existing frames removable and replaceable with frames molded from fiberglass reinforced polyarylene (Stilan)	--
Seat bottom shrouds	Existing shrouds coated with blue Fluorel L-3203-6 and overcoated with Kel-F FX 703	Satisfactory	No change required	--
Cockpit ceiling	Fiberglass, coated with oyster-white Fluorel L-3961-5 overcoated with Kel-F FX 703	Satisfactory	No change required	--
Padding for passenger compartment, entrance, and galley carpets	Mobay HR foam impregnated with ADP and overcoated with Fluorel L-3203-6	Satisfactory	No change required	--
Baggage compartment carpeting	NASA no. 1 - Fire-retardant acrylic-coated fiberglass	Satisfactory	No change required	--
	NASA no. 2 - Wool (100 percent), blue-green	Satisfactory	No change required	--

TABLE V.- GULFSTREAM 3 AND 4 REFURBISHMENT EVALUATION

Material application	Material initially installed	Performance	Material currently installed	Performance
Seat back cushions	Scott HR foam impregnated with ADP and overcoated with Fluorel L-3206-6	Satisfactory	No change required	--
Seat flotation cushions	Composite of Ensolite foam and Scott HR foam impregnated with ADP and overcoated with Fluorel L-3206-6	Satisfactory	No change required	--
Crew seat upholstery	Fire-retardant lambswool (fig. 6)	Satisfactory	No change required	--
Crew seat trim and armrests	Fire-retardant leather, blue	Satisfactory	No change required	--
Passenger seat upholstery	NASA no. 3 - Wool/Leavil blend fabric upholstery and modacrylic ticking	Satisfactory	No change required	--
	NASA no. 4 - Wool, solid blue, and modacrylic ticking (fig. 7)	Satisfactory	No change required	--
Passenger seat armrests and footrests	Fire-retardant leather, blue	Satisfactory	No change required	--
Headrest covers	Disposable fire-retardant nonwoven cellulose	Satisfactory	No change required	--
Entrance, galley, and lavatory floors and lower sidewalls	Wool (100 percent), blue-black pile installed as an interim material	Not recommended because the pile retains debris and liquids spilled on the carpet	Kel-F 2401B coated asbestos linoleum-type can be supplied as an alternate upon request	--
Carpeting, passenger cabin	Wool (100 percent), blue-black pile	Satisfactory	No change required	--
Side curtains	NASA no. 4 - Flovan-treated wool, blue, lined with Beta Fiberglas, white	Satisfactory	No change required	--
	NASA no. 3 - Fire-retardant cotton with fire-retardant cotton lining	Satisfactory	No change required	--
Coat closet drape	Flovan-treated wool, blue, reversible curtain	Satisfactory	No change required	--
Acoustical entrance drape	NASA no. 3 - Nomex scrim-supported Nomex felt sandwiched between two layers of Kel-F 2401E coated nylon	Satisfactory	No change required	--
	NASA no. 4 - Nomex scrim-supported Nomex felt sandwiched between two layers of blue Fluorel L-3203-6 coated Nomex fabric overcoated with Kel-F FX 703	Satisfactory	No change required	--
Cockpit drape	Flovan-treated wool, blue	Satisfactory	No change required	--
Headliner and side panels	White Fluorel L-3961-5 coated fiberglass, overcoated with Kel-F FX 703	Satisfactory	No change required	--
Cockpit ceiling	NASA no. 3 - Fiberglass coated with oyster-white Fluorel L-3961-5 overcoated with Kel-F FX 703	Satisfactory	No change required	--
	NASA no. 4 - Because of the ceiling design, currently installed Royalite was retained and refinished	Satisfactory	No change required	--
Window panels	Fiberglass, coated with white Fluorel L-3961-5 overcoated with Kel-F FX 703	Satisfactory	No change required	--

TABLE V.- GULFSTREAM 3 AND 4 REFURBISHMENT EVALUATION - Concluded

Material application	Material initially installed	Performance	Material currently installed	Performance
Entrance wall	NASA no. 4 - Blue Fluorel L-3203-6 coated Nomex fabric, overcoated with Kel-F FX 703 (fig. 5)	Satisfactory	No change required	--
	NASA no. 3 - Kel-F 2401E coated nylon	Satisfactory	No change required	--
Lavatory, steward room and coat closet walls	Durette coated with white Fluorel L-3961-5, overcoated with Kel-F FX 703; 0.3175 cm (0.125 in.) Pyrell padding coated with Fluorel L-3203-6	Satisfactory	No change required	--
Cabin air-duct shrouds	White Fluorel L-3961-5 coated fiberglass, overcoated with Kel-F FX 703	Satisfactory	No change required	--
Toilet shrouds	Blue Kel-F 2401E coated nylon	Satisfactory	No change required	--
Window frames	Acrylonitrile butadiene styrene coated with Fluorel L-3961-5, overcoated with Kel-F FX 703	Satisfactory	No change required	--
Seat bottom shrouds	NASA no. 3 - Shrouds painted with blue pigmented Kel-F FX 703	Satisfactory	No change required	--
	NASA no. 4 - Fire-retardant leather installed	Satisfactory	No change required	--
Padding for passenger compartment, entrance, and galley carpets	Mobay HR foam impregnated with ADP and overcoated with Fluorel L-3203-6	Satisfactory	No change required	--
Baggage compartment carpeting	Wool (100 percent), blue-black	Satisfactory	No change required	--

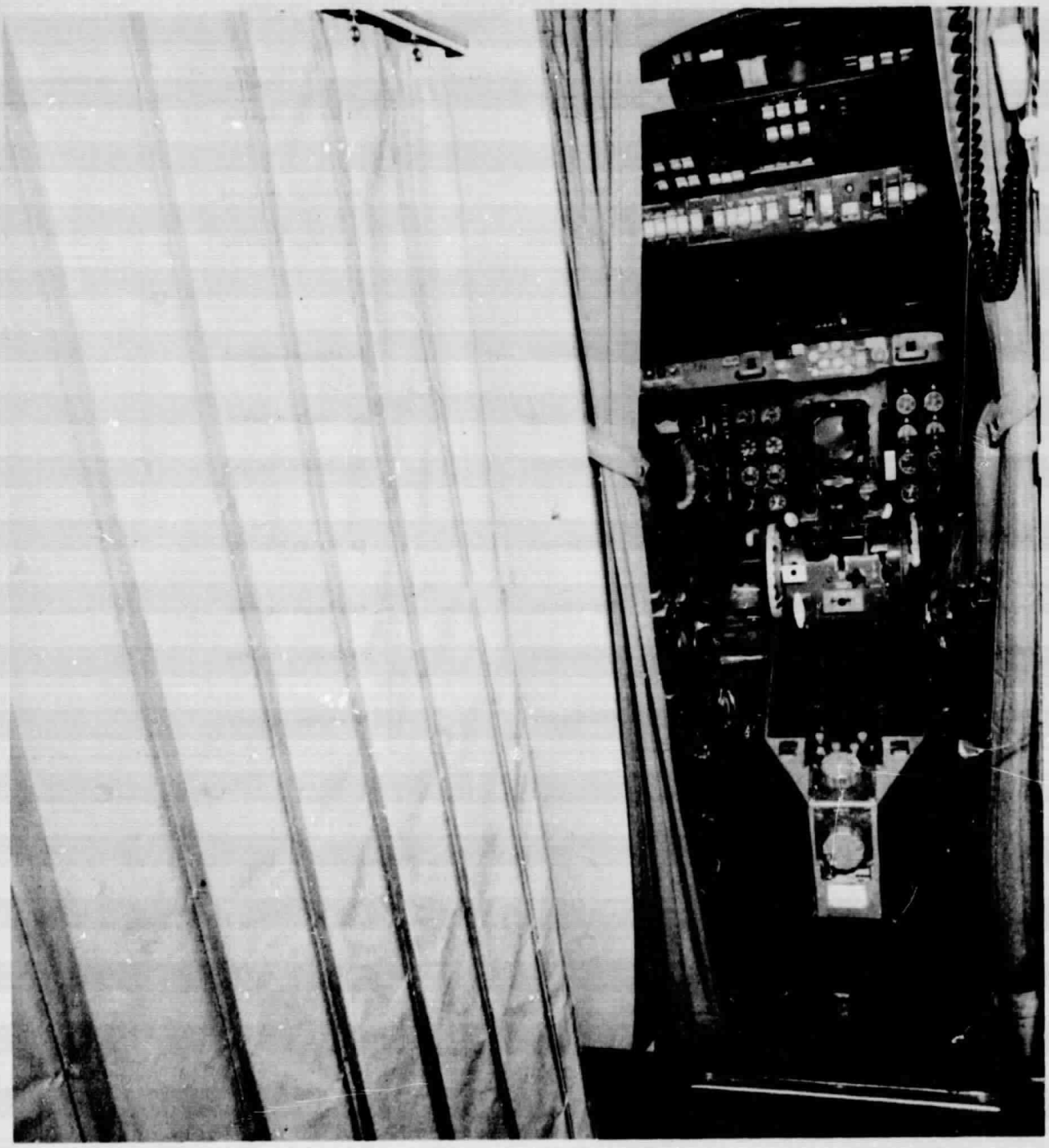

Figure 1.- Gulfstream 2 acoustical entrance drape coating; adhesion failure noted at latch area and at entrance wall edge.

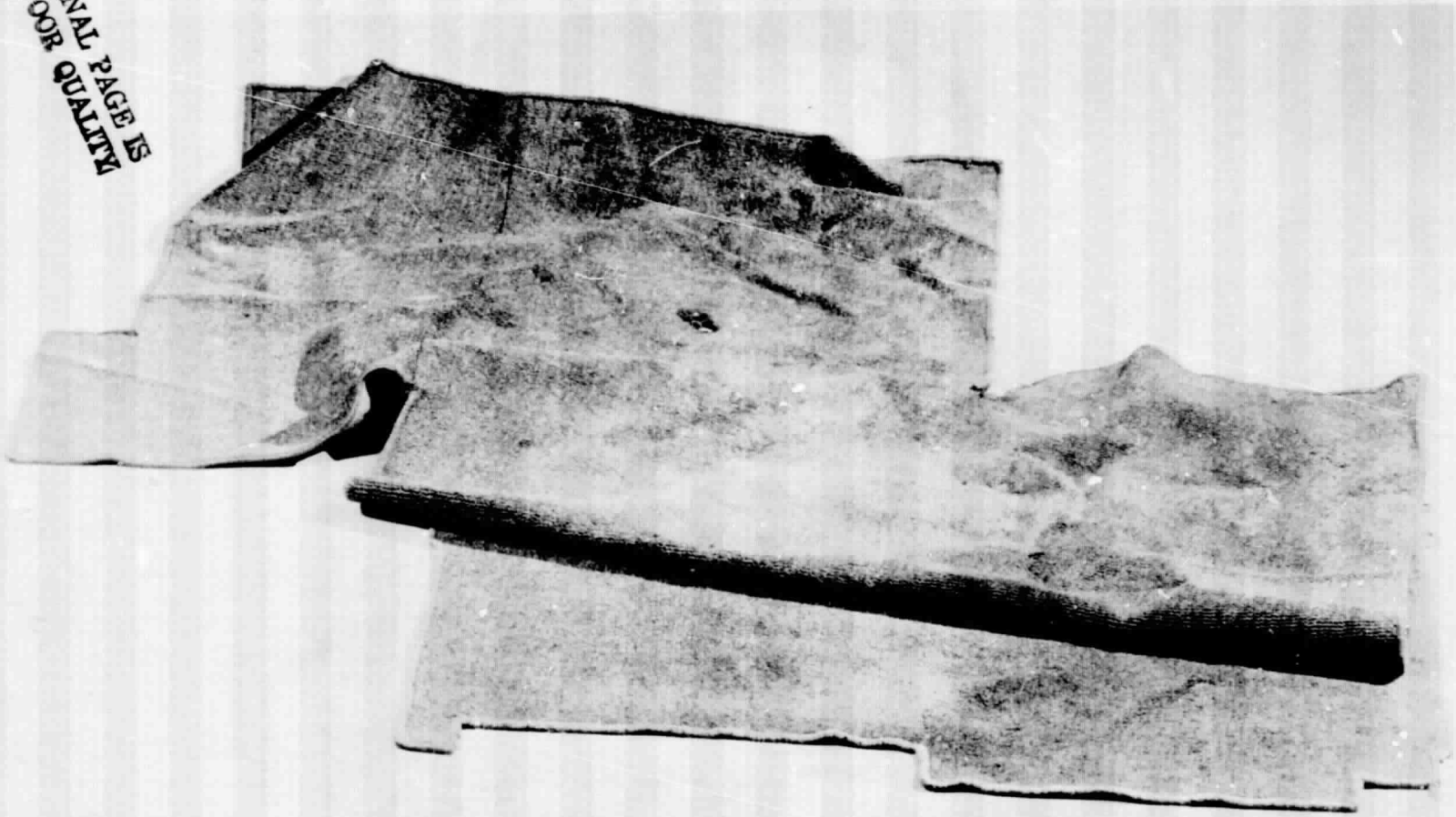

Figure 2.- Gulfstream 2 entrance and galley fire-retardant acrylic-coated fiberglass carpet after 1 month of service.

Figure 3.- Gulfstream 2 passenger cabin ceiling, curtains, and side panels in excellent condition after 2 years of service.

Figure 4.- Gulfstream 2 passenger cabin wool/Leavil-blend seat upholstery.

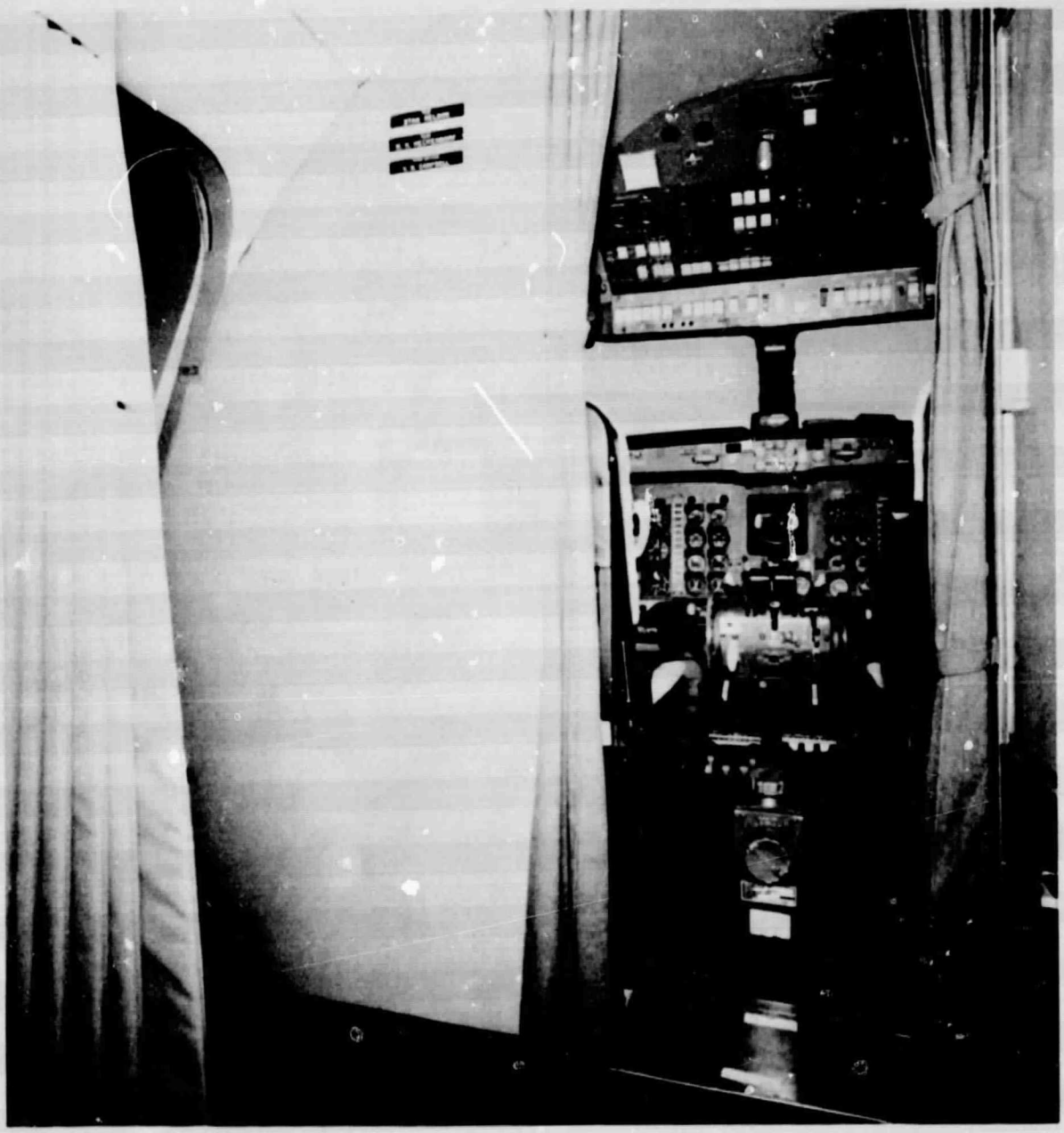

Figure 5.- Gulfstream 4 blue Fluorel-coated Nomex entrance wall covering and acoustical entrance drape.

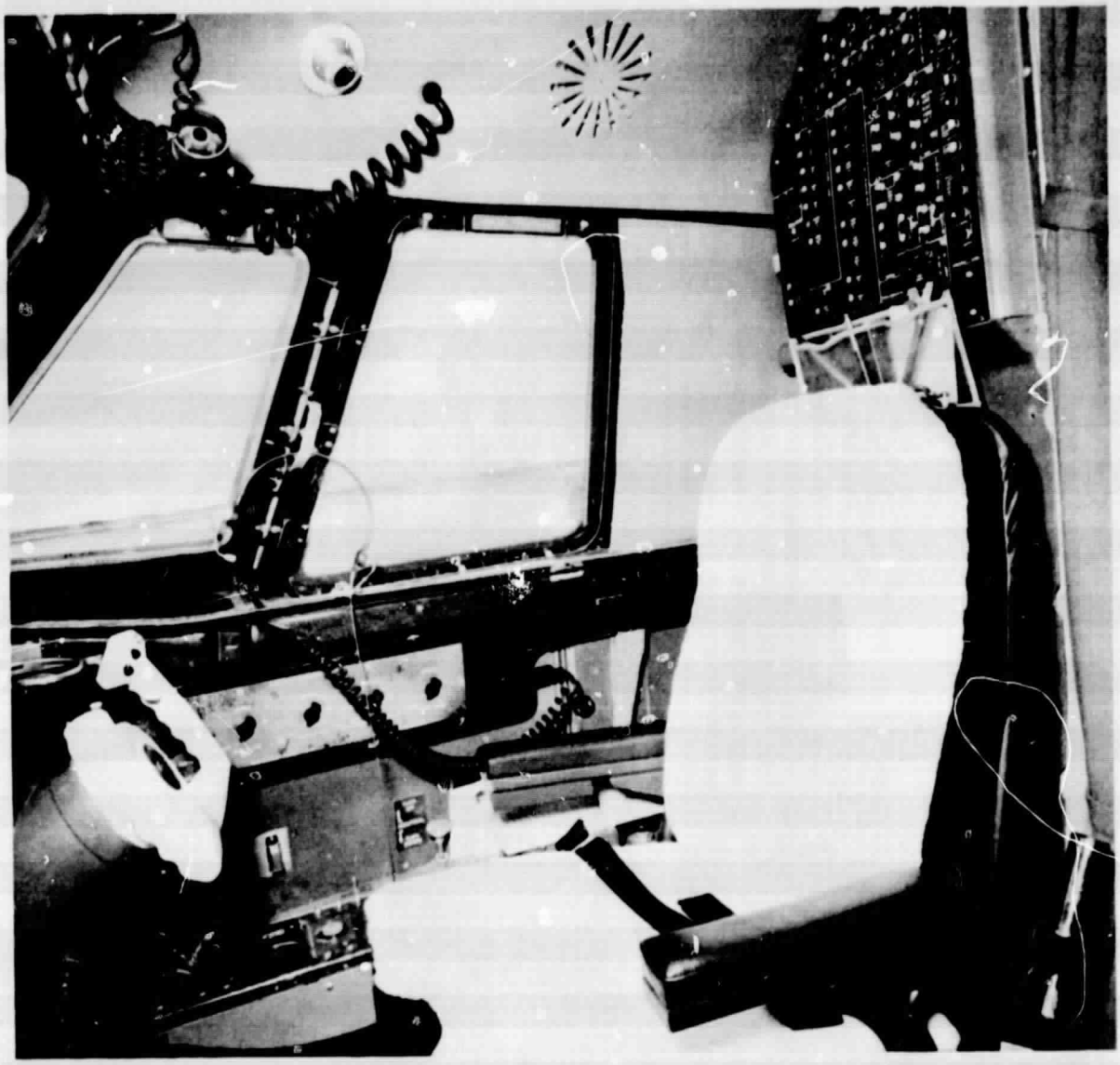

Figure 6.- Gulfstream 2 crew seat upholstery, fire-retardant lambswool and blue fire-retardant leather trim; cockpit drape, blue Flovan-treated wool.

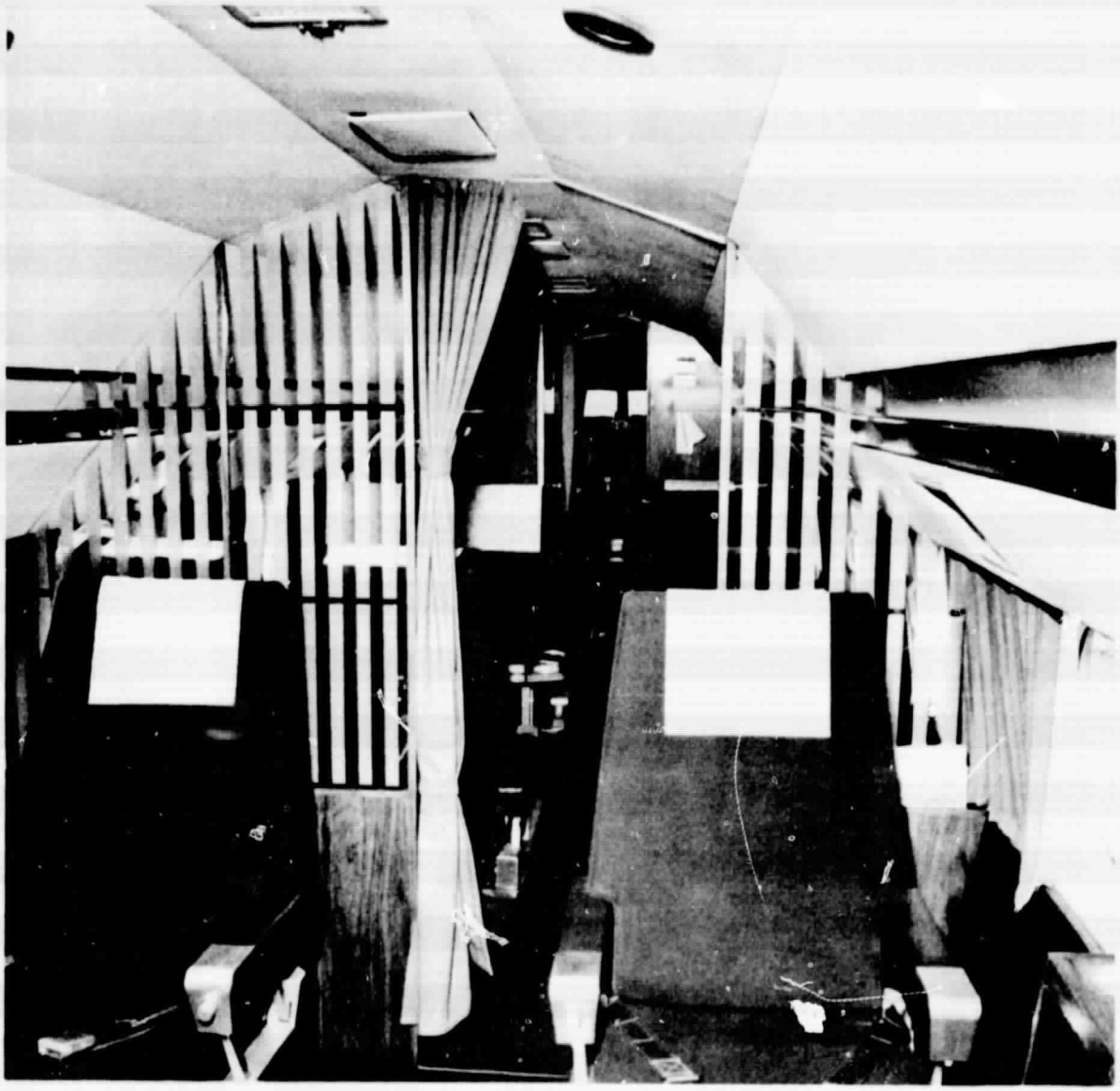

Figure 7.- Gulfstream 4 solid blue upholstery and blue 100-percent wool carpet.

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